Water Level Response for Over Extraction in Western Parts of Al-Jafer Basin (Jordan)

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Abstract

The study area covers the western part of Al-Jafer Basin, which enjoys a Mediterranean climate. The major aquifer in the study area (A7B2) is mostly unconfined, and the recharge rate is the highest within the basin. In this rural agricultural area, irrigated agriculture has increased to cover more than two thousand hectares over the last 25 years. This increase has been accompanied by an increasing agricultural ground-water withdrawal. This is attributed to the fact that rainfall in the region is insufficient to support the introduced crops. Because abstractions have greatly exceeded aquifer recharge, the water table has declined considerably. Using ArcGIS Algebra maps to compare between potentiometric map from predevelopment time with ground water level at the end of 2012, results have shown that water-level decline up to 165 meters. The analysis of abstraction data shows that agriculture is not solely responsible, even though private irrigation abstractions have removed at least two times the amount abstracted by government wells. Interpolating the available water level data shows that the geological structure conditions don't facilitate groundwater movements between geological blocks, where the main faults act as barriers. The historical data about spring discharge shows that except on spring all others become dry or suffer severe decrease in discharge.

Key words: water level drawdown, over abstraction, Al- Jafer basin, water uses

1. Introduction

Jordan in one of the poorest countries worldwide in renewable water resources (Bertelsmann Stiftung 2012; N. Hadadeen, 2011). The total available water resources on national scale is already extremely limited and is far below the water poverty line of (1000) m3 per capita per year (FAO 1997;Winpenny 2000). Using all available water resources (surface ground and unconventional resources), the capita share is about 140m3 per year (Jiris 2012; Isehunwa, et al. 2013; JWS 2009). The rapid growth of population in Jordan augments the stresses on the water resources in the same proportion. This rapid increase in the population is due to a high rate of natural growth and a sporadic large in migration of refugees (Ramírez, et al. 2011). Just in the past two years, Jordan received more than 500,000 Syrian refugees, which represent 8% of the total active population of the country (Wikipedia 2014).

The total renewable water resources in Jordan are estimated in 650 -810 million of cubic meters per year (Margane et al. 2008; El-Naser 2012). About 60% comes from surface water whereas about 30% from ground water and the rest 10% from unconventional water resources such as treated and desalinated water (Shatanawi, M. 2011).

The total estimate recharge for all groundwater basins in Jordan is in 275– 300 million m^3/ year (El-Naqa and El-Shayeb 2009; Abu Sharar et al. 2005; Abu- Jaber 2010). The annual average of total registered abstraction from those basins in the last 10 years ranges from 450 – 550 mm3/ year (El- Naser 2012). That almost agree with the 2011annual report of the ministry of water and irrigation , which indicates that the abstraction from the twelve basins is more than 200% of the annual recharge, which means a severe overexploitation.

Nowadays, only 3 out of the 12 groundwater basins in Jordan don't suffer a net deficit (Fig 1). Even more, the abstraction quantities don't include the illegal pumpage.

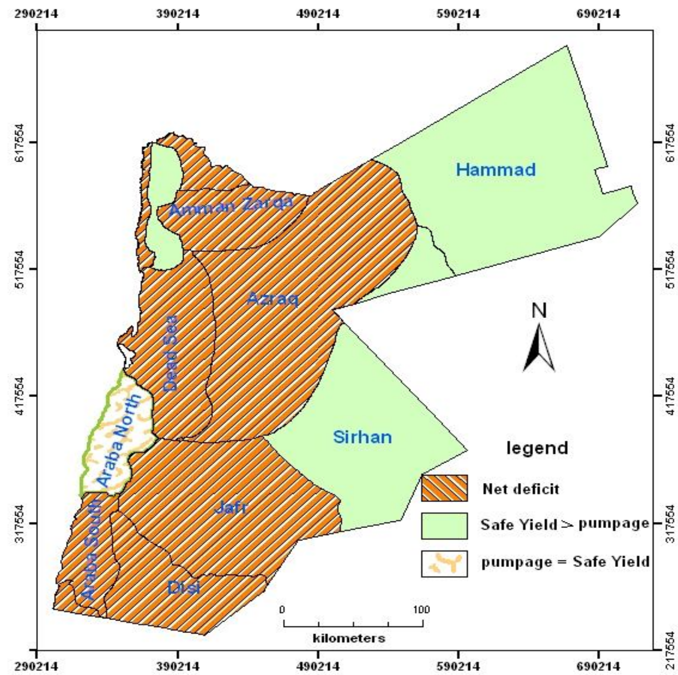

Fig. 1: Jordan groundwater deficit.

2.1. Al-Jafer Ground Water Basin

Al-Jafer ground water basin is the largest one in the south of Jordan with an area about 12450 km^2. The majority of the basin area receives less than 50mm/ year as the long term average rainfall map shows (fig.2). The catchment area of Al- Jafer basin is located at elevations ranging between 1750 m a. s. l. in the western highlands and 850 m a. s. l. in Al-Jafer playa. The drainage pattern is centripetal from marginal highlands to central plato (El- Naqa and Rimawi 2012). Since the ends of eighties of the last century,

Al -Jafer basin hosts an intensive agriculture projects and the most recent and the largest phosphate mines in Jordan (Abu-Hamatteh 2007; NRA 2006). Those two sectors consume about 67 % of the total water consumption in Al-Jafer basin area, while the domestic sector consume the rest proportion (MWI 2007)

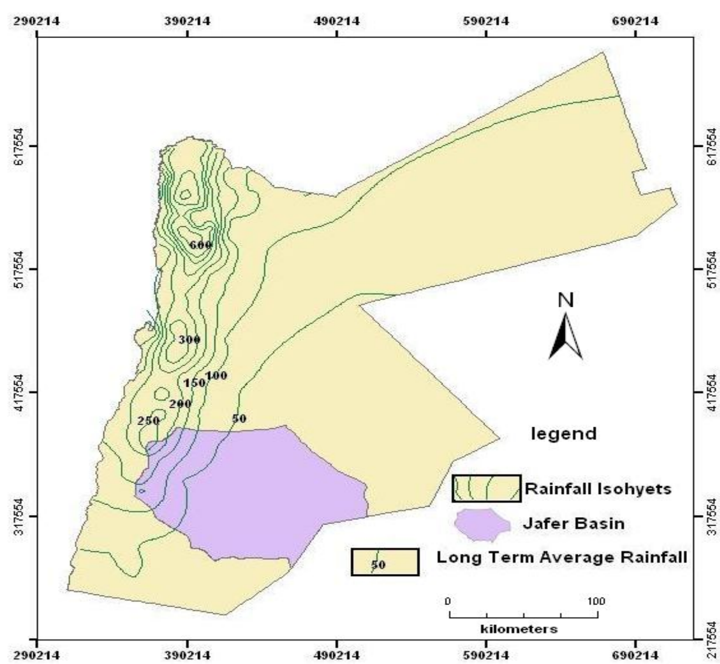

Fig. 2: Long term rainfall distribution in Jordan

2.2. Study Area

The study area represents the western part of Al-Jafer basin and includes terrene in five districts of Maan governorate (fig. 3). The study area also lies at elevations between 1050 m above sea level (a.s.l.) in the eastern parts and 1750 m a.s.l. in the western highlands.

Four main aquifers are underneath the study area; B4/B5 outcropping in the eastern parts, A7/B2 outcropping in the western parts and the deep aquifers which include Kurnub and Disi. The actual abstractions in the study area seems to be restricted to the A7/B2 aquifer, where the deep aquifer system is deep and is not explored, whereas B4/B5 aquifer is of little significance.

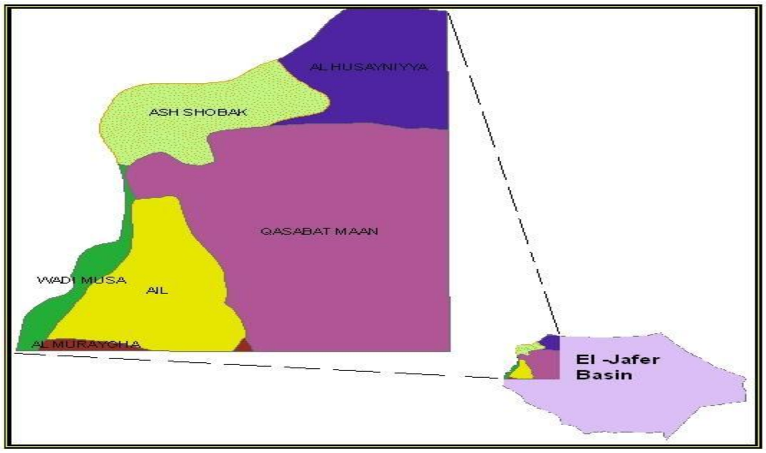

Fig. 3: Study area map

The principal aquifer system in the study area (A7/B2) is mainly of carbonate rocks with very good water quality. In the western parts of the study area, the aquifer system is exposed at the surface, while in the eastern parts it is confined by overlying thick impervious argillaceous unit of the Muwaqqar Formation (B3). Fig 4 presents a simplified geological map for the study area while table 1 resumes the geological and hydrogeological classification of rock units which appear in the geological map.

The western highlands area of Al-Jafer basin is of a special importance because it is practically the recharge area for the whole Al -Jafer basin, especially the outcropping aquifers. Fig. 2 shows that the annual rainfall in the study area, being very much higher than the other parts of the basin. Furthermore, a considerable proportion of the rainfall quantity is in form of snow, which enhances the infiltration process and thereafter groundwater recharge (Yong and Yongxin, 2005).

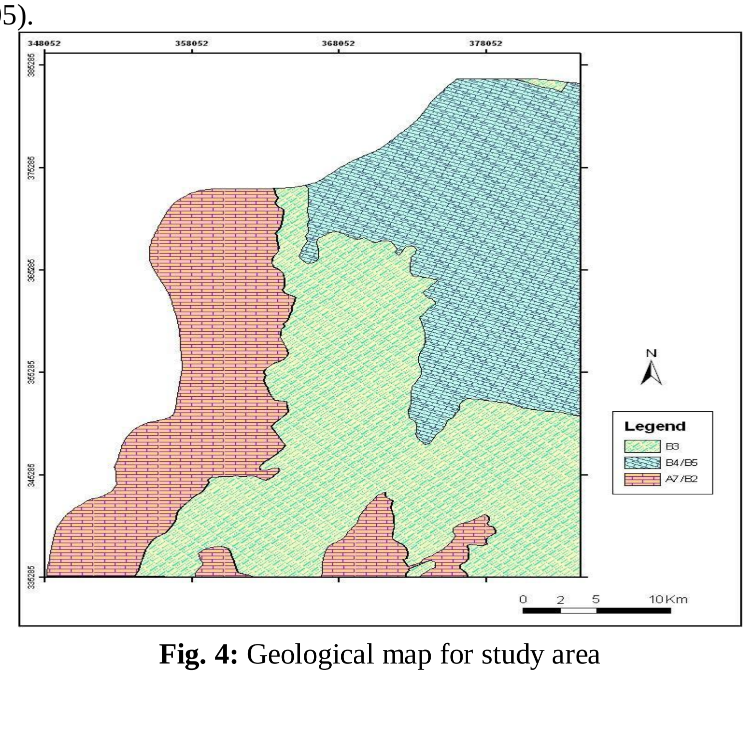

Fig. 4: Geological map for study area

Table 1: Geological and hydrogelogical classification of rock units

Geological Scale			Hydrogeological Character		
Era	period	Epoch	**Group**	Formation	symbol
Cenozoic	Tertiary	Eocene	**Balqa**	Wadi Shalaleh	**B5**
Mesozoic	Cretaceous	Paleocene		Rijam Aquifer	**B4**
				Muwaqar Aquitard	**B3**
		MeastnchtIan Companian		Amman Aquifer	**B2**
		Santonian		UmmGhudran (Aquitard)	**B1**
		Turonian	**Ajlun**	Wadi Sir (Aquifer)	**A7**

3. Methods

The predevelopment ground water surface was established using the data of the last eighties of the last century (BGR-MWI 1991). The water level contour from ground water flow pattern map in the A7/B2 was digitized then extrapolated to construct an accepted predevelopment groundwater surface in the study area.

The post development groundwater surface was constructed using groundwater monitoring-well data during the period 1991-2012, and the retrieved information from drilled abstraction wells during the initial pumping test. Most recent drilled wells drive good information with regard to actual static water level. The groundwater level response for the groundwater exploitation process is assumed to be the net change in the ground water level. This change is the algebraic subtraction of post development surface values from predevelopment surface values.

The monthly groundwater level data for monitoring well in the study area was employed to produce a hydrograph to each well showing its response for abstraction and natural recharge.

The springs discharge in the study area was used to depict the spatial extension of groundwater level change and to enhance the conclusions regarding to water level response.

4. Results

All the monitoring wells show a net drawdown in groundwater level ranging from Almost one meter in the well G3163 to 165m in the well G1405. However a drawdowns between 10-90m seem to be more common, such as in the wells G3146, G3147, and G1346 (fig. 5).

The comparison between the predevelopment water level and actual water level shows a drop in water level from less than 25m up to more than 100 meter (fig 6). The drawdown is more severe in the central north and central south parts of the study area.

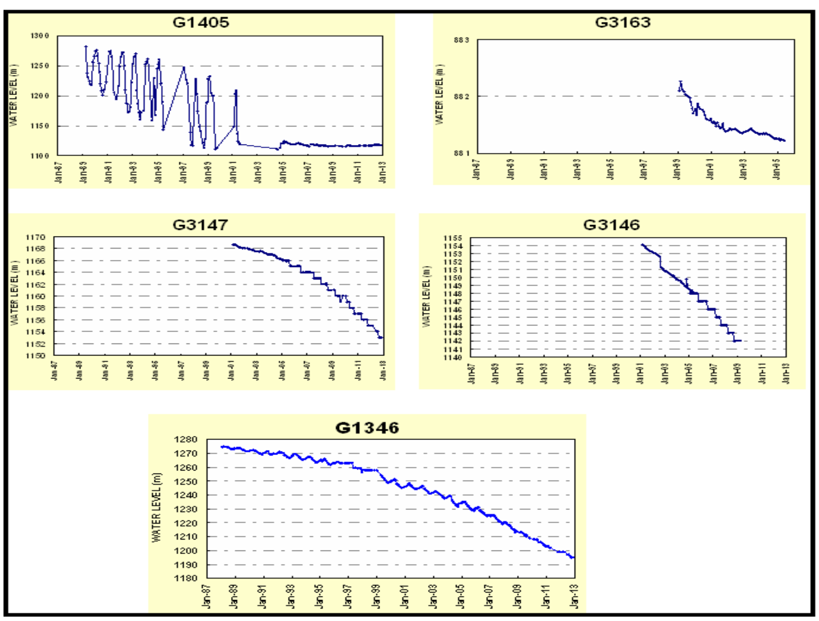

Fig. 5: Selected hydrographs for monitoring wells in study area

There were 29 springs in the study area in the predevelopment time. By 2007, 11 of them become dry, 16 of them had less flow and only two of them remained without real change in their flows or there were not enough data to judge (fig 7).

The abstraction wells in the study area is more than 70, among them 34 are private and 37 are governmental. Table2 shows their uses and pumping g quantities, where figure 8 shows their distribution.

5. Discussion

The ground water drawdown is normally due to a decrease in the net recharge or an increase in abstraction, or a combination of both. In the study area, there is no serious study that proved any climate change or a decrease in the rainfall. So, it is clear that any groundwater level change will be attributed to an over abstraction.

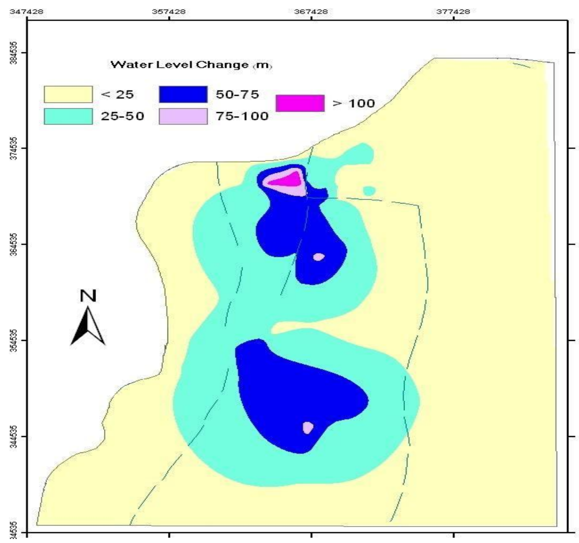

Fig. 6: Groundwater level change during the period 1990 to 2012

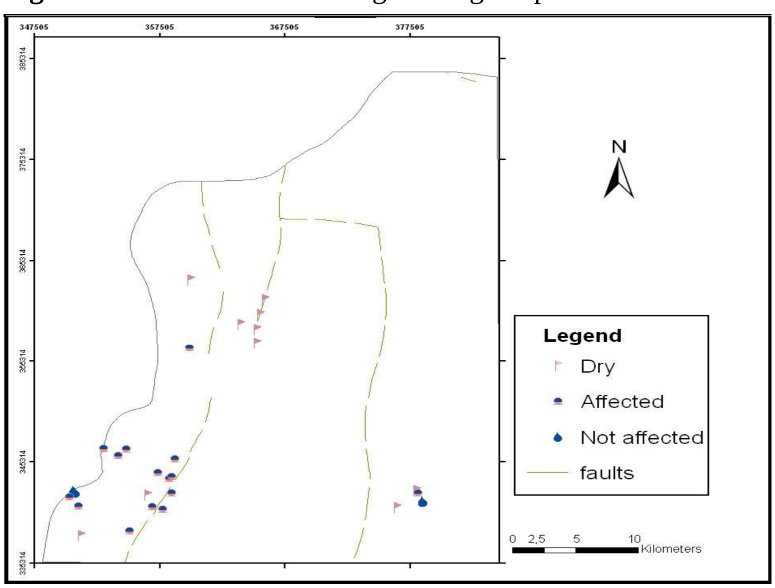

Fig. 7: Spring state in the study area

Table 2: Well's production (m^3) in the study area for 2003 year

Owner	Number of wells	Use of water		
		Domestic	Irrigation	pastoral
Private	34	-	7117332	-
Governmental	37	5180844	1266045	3116

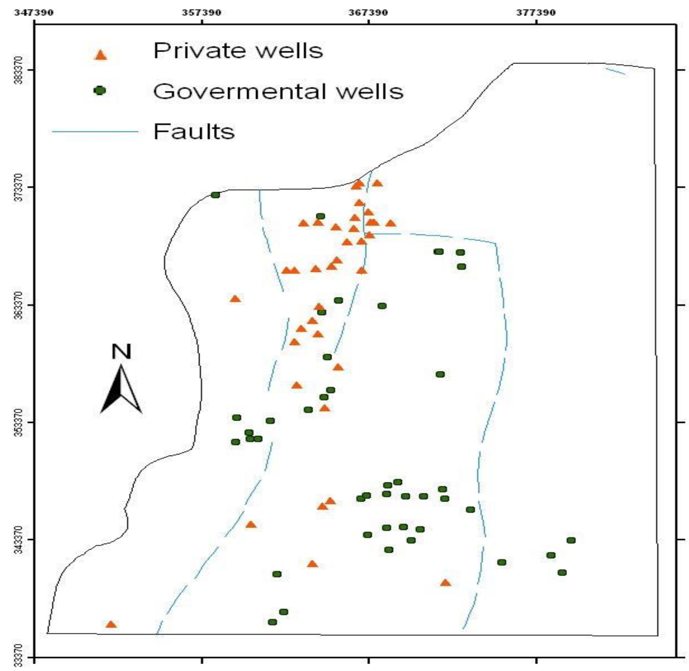

Fig. 8: Abstraction wells distribution in the study area

The responsibility of each sector of water users is a function of its abstraction quantities. The total abstraction from the study area is higher than the safe yield of the entire basin. However, the study area represents less than 10% of the basin area. If any sector stops completely and immediately its abstraction, the basin will keep suffering of the deficit conditions. So, the over abstraction control is a trans-sectoral issue where all the stakeholder should collaborate.

The two locations with the highest drawdown in study area (fig.6), almost coincide with location of major well fields in study area (fig.8). In the northern pate where the drawdown in the water level exceeds 100m, a cluster of more than 20 private wells penetrate the aquifer. In the same way, the southern high drawdown spot is surrounded by a huge governmental well field.

The drying or discharge decrease of springs reveal a break down of the historical formula of inputs and outputs. However, discharge decrease for springs could happen when the abstraction is within the safe yield. The safe yield requires that the abstraction should be equal or les than recharge. When the induce abstraction equals the recharge, this results in no water for springs. So, wherever the springs have a social and environmental importance, there discharge should be included in "out" side and the induced abstraction should be always less than recharge "ins" to guarantee some springs flow.

In most cases, the location of dried springs is in the vicinity of abstraction well fields or very close to main faults in the study area. That might explain the relation between over pumping and springs drying. The pumpage produces a cone of depression, where the water level gets beneath the spring level. The faults seem to act as barriers. They limit the groundwater to cross from one side to another, therefore, the springs closer to those faults become dry faster.

6. Conclusions

1. The total groundwater abstraction from the study area is higher than safe yield of entire Al-Jafer basin.
2. The deficit in Al-Jafer basin is higher than the total abstraction of any single sector.
3. To achieve a balance between the recharge and abstraction for Al-Jafer basin, two or more sectors have to collaborate.
4. The groundwater level declines in the study area ranging from few meters up to 165m.
5. The majority of springs in the study area became dry as a result of water level drawdown.
6. The main faults in the study area act as barriers, where they limit the groundwater flow through them.

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